Cleaning for sub 0.1 μm Technology: a Particular Challenge

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One of the major challenges in surface preparation technology that can impact the yield of sub 0.1-μm devices is particle addition and removal. The attribution of the cleaning process to the total number of particles on the wafer is currently underestimated. Cleaning processes are deemed to remove particles, but they also add particles.

In a production environment, the performance of a cleaning tool is daily measured by cleaning almost clean wafers. The number of particles after cleaning minus the number of particles before cleaning is a measure of the cleaning-process performance, *i.e.*, the particles add (Δx). To date, it is assumed that none of the particles present on the surface are removed. Consequently, the measured number of added particles is too lower than in reality. Statistical analysis of this day-to-day monitoring is done using normal distribution of the Δx. Correlation of Δx with yield or even short-loop capacitor test data is poor.

A new statistical model to determine the cleaning performance of cleaning tools is presented. The basis of this model is that a cleaning tool removes and adds particles indeed. These two processes are in dynamic equilibrium. It is assumed that the average adhesion strength of the particles is normally distributed.

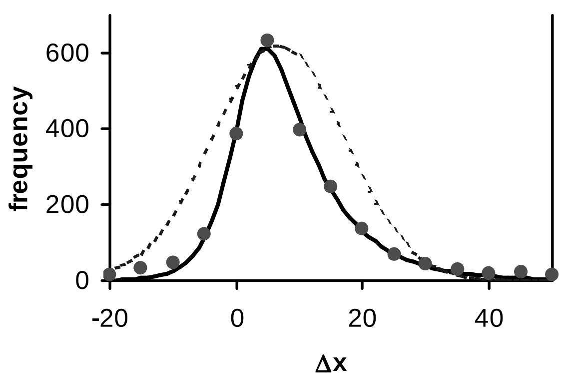

Figure 1. Particle addition data from particle monitoring.

In Figure 1, particle monitor data from one tool set over a period of one year are shown and the occurrence of a certain Δx is plotted as dots. The dashed line is the Δx distribution using the current normal distribution model. The solid line is a curve fit using the new statistical model.

The fitting parameters used to fit the fab data with the new model have a meaning. For example, one of these fitting parameters describes particle addition. In the example, the average particle addition is found to be 62, while the normal distribution peaks at 6.6. This is a significant difference. Furthermore, a second parameter describes the particle removal efficiency of unknown particles, which is in the case 66%.

If these new particle addition data are put into a yield model (Poisson distribution) a better correlation between the defects found with capacitor tests and particle monitor is obtained. In Figure 2 the particle addition numbers using the Normal distribution and the new statistical model of the separate tools have been translated to a number of defects on a device.

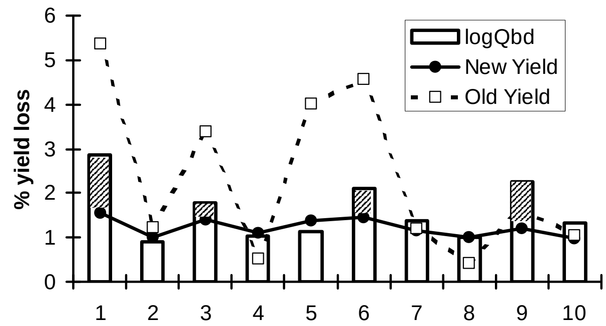

Figure 2. Relation between particle addition monitor and yield loss in capacitor test (log Q_{bd}) per tool (1 to 10).

The relation between Q_{bd} yield and average particle addition using the Normal distribution is poor indeed. Using the new model the relation is much better. Almost all of the Q_{bd} yield loss can be explained by particles addition by the cleaning tool.

This new method has consequences for process control of tools. Process control may become impossible if the measured particle size is much larger than half of the design rule. In that case, the number of particles, of the size measured and added by the tool, is too small to allow statistical analysis and control.

Next to the number of particles added also a performance indicator for the particle removal is required. Up till now, there is no method that can unambiguously demonstrate particle removal efficiency. This is due to differences in test-particle choices, preparation method of test wafers, and the surface properties of the test wafer. A general accepted test method is lacking.

Finally, methods for the removal of particles are discussed. Processes and tools show to have limitation and conflict with numbers set in roadmaps.